

Emergence of Constructor-based Irreversibility in Quantum Systems



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Constructor Theory

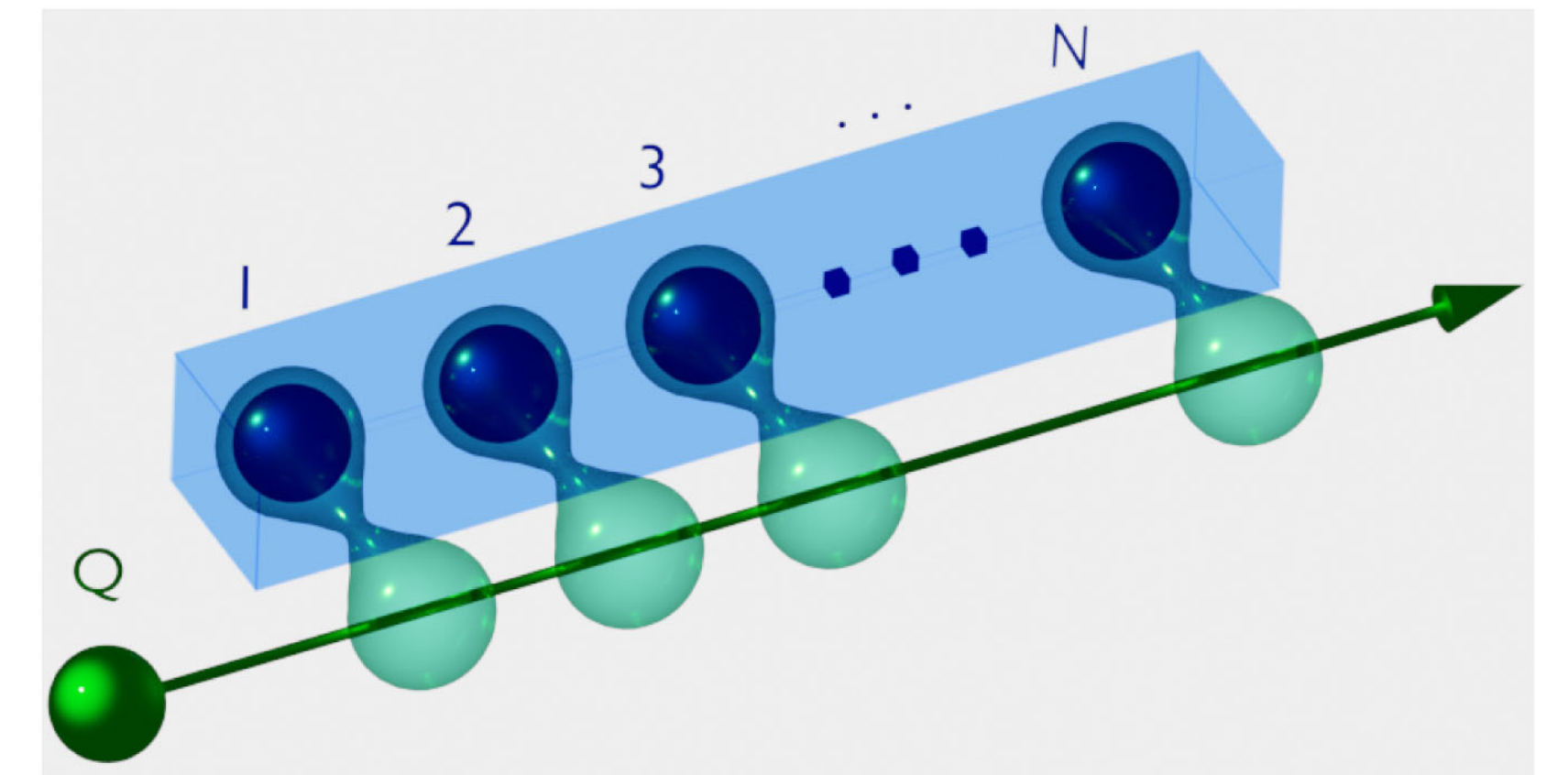
- A Constructor is a system able to perform a given task on another system while retaining the ability to do it again.
- We formalise this property defining the Relative Deterioration of a system [Marletto_2022]
- A task is possible if there is a Constructor able to perform it

Emergence of Irreversibility

- Consider a task T that transforms a state ρ_x to a state ρ_y , $T: \rho_x \rightarrow \rho_y$
- The transposed task T^\sim is the task that transform ρ_y to ρ_x , $T^\sim: \rho_y \rightarrow \rho_x$
- We show that exists a task T that is possible while its transposed T^\sim is not possible

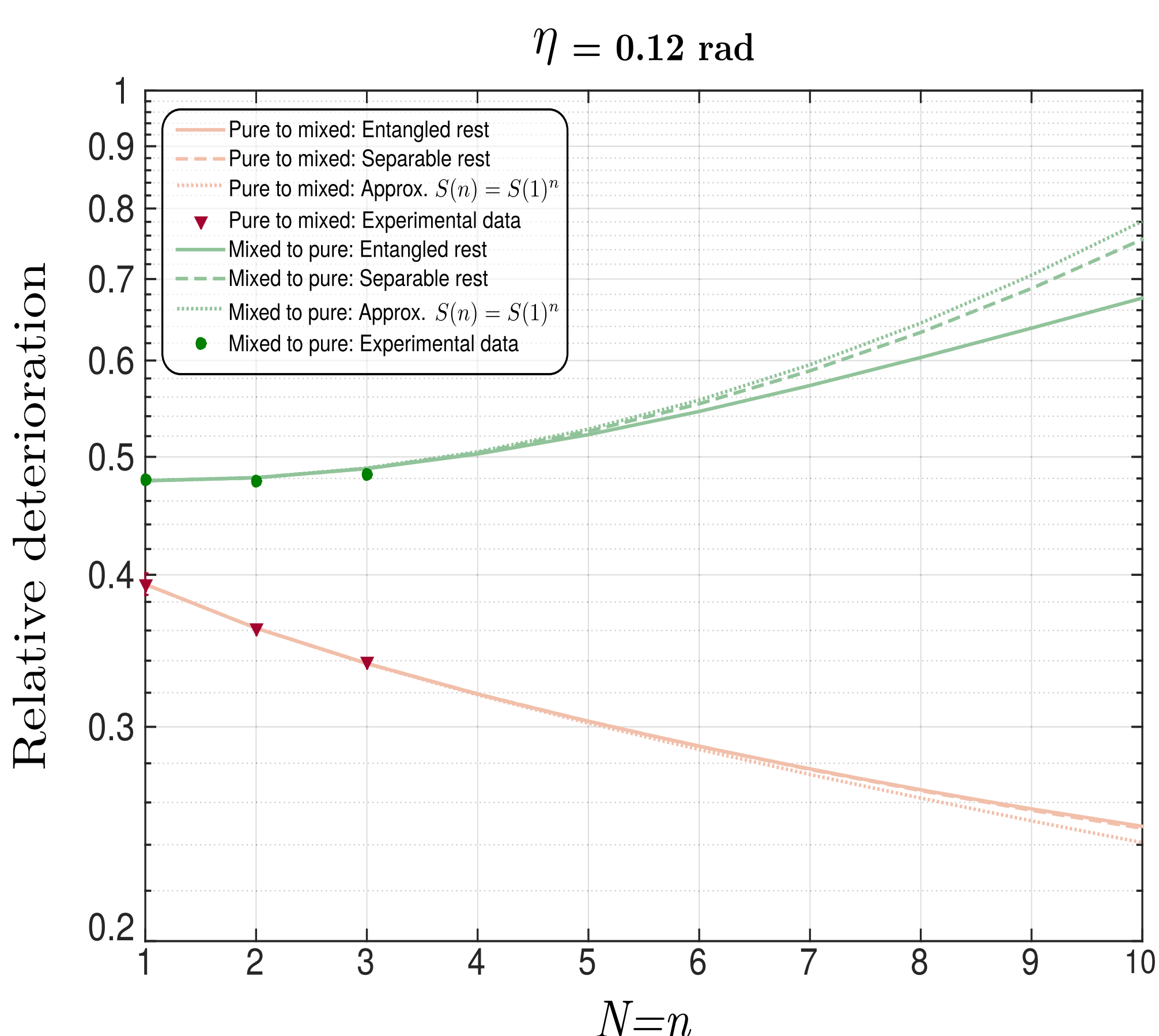
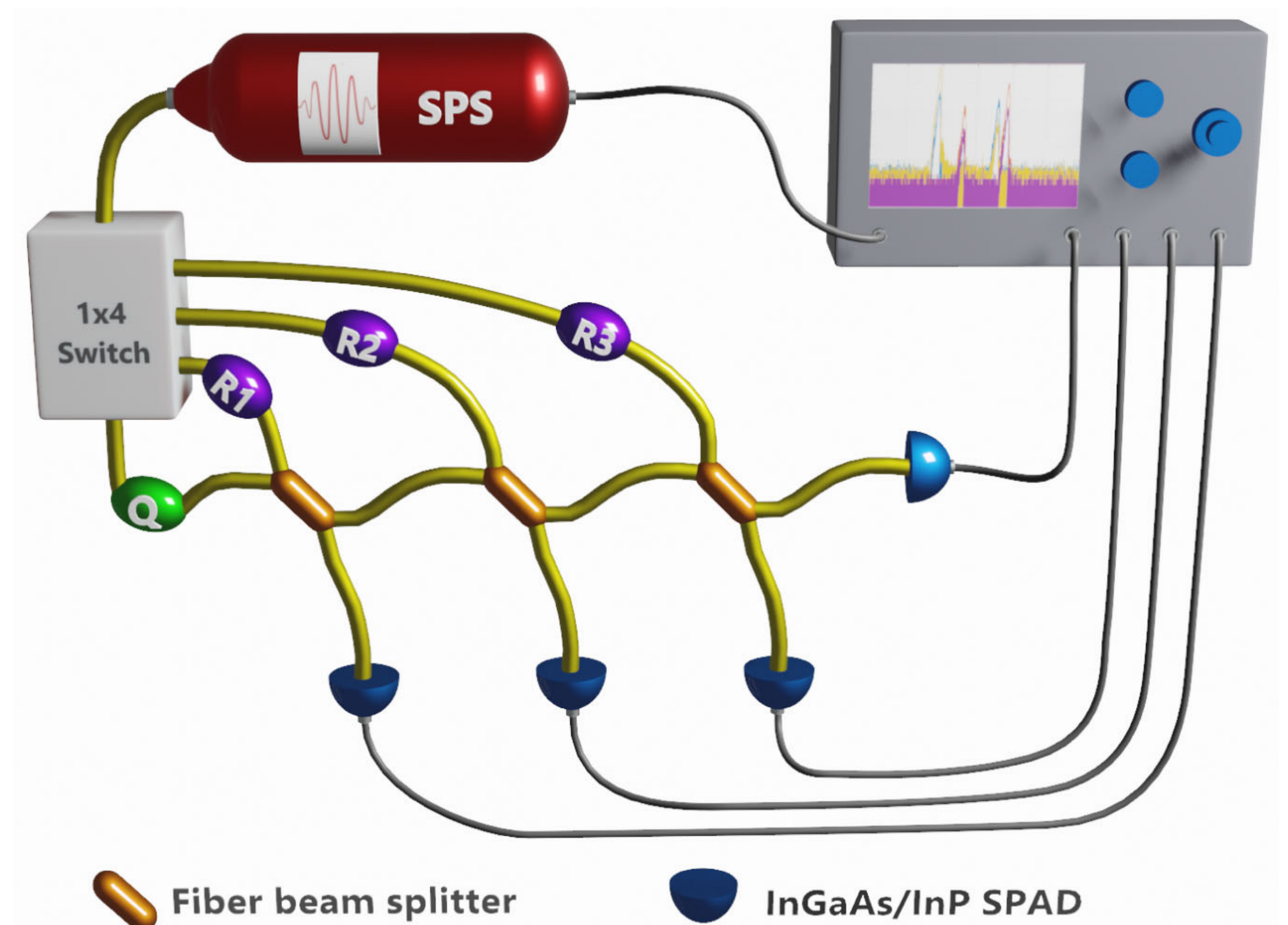
The Homogeniser

- The Task considered is the Homogenisation of ρ_x to ρ_y
- The machine performing this transformation is the Quantum Homogeniser, operating through sequential partial swap between ρ_x and N copies of ρ_y



Quantum Optics Experiment

- We realise the Quantum Homogenisation process by using single-photon qubits at 1550 nm and fiber beam splitters
- The single photon is the system ρ_x
- The other 3 photons plays the role of the copies ρ_y
- The partial swap is realised using beam splitters



- For the homogenisation of a **Pure** state to a **Mixed** state, the relative deterioration goes to zero
- For the homogenisation of a **Mixed** state to a **Pure** state, the relative deterioration goes to infinity
- For **Pure** to **Mixed** the constructor exists. The task is possible.
- For **Mixed** to **Pure** the constructor does not exist. The task is not possible
- In this asymmetry consists the emergence of irreversibility

Marletto_2022] C. Marletto et al., Emergence of Constructor-based Irreversibility in Quantum Systems: Theory and Experiment, (2022) Phys. Rev. Lett. 128, 080401.